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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Reed W. Bailey, Director
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE

Ogden, Utah

February 1962

A PROGRESS REPORT OF A STUDY ON THE SUSCEPTIBILITY OF OLD-GROWTH PONDEROSA PINE IN MONTANA TO BARK BEETLE ATTACKS

(Line Project FS-2-e1-1-INT)

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TABLE OF CONTENTS

	Page
SUMMARY	3
INTRODUCTION	5
HISTORICAL BACKGROUND	6
METHODS OF STUDY	7
RESULTS	8
Physical Structure of Pine Stands	8
Pine Tree Mortality	12
Susceptibility of Pine Trees To Bark Beetles	14
Susceptibility of Pine Stands to Bark Beetles	18
DISCUSSION	21
FUTURE PLANS	22
ACKNOWLEDGMENTS	23
LITERATURE CITED	24
UNPUBLISHED REPORTS AND THESES CITED	25
APPENDIX	26
Ponderosa Pine Risk Rating System	27
Penalty System of Rating Tree Risk	28
Plot Establishment Information	29
Trees and Volumes Per Acre on Plots	31
Distribution of Trees by Risk Ratings	33

SUMMARY

The report describes progress and preliminary results on a study in Montana to determine how well the Ponderosa Pine Risk Rating System can identify the trees most frequently killed by the western pine beetle (Dendroctonus brevicomis Lec.). The rating system has been used for this purpose with marked success in interior ponderosa pine stands in the Pacific Coast States since it was perfected in 1937.

The study, started in 1948, involves 35 plots with an aggregate area of 553 acres in typical old-growth, merchantable ponderosa pine stands west of the Continental Divide. Periodic plot examinations determine possible changes in current tree vigor and the amount and causes of death among the nearly 12,000 risk-rated ponderosa pine trees over 11.1 inches in diameter.

Provisional and some reasonably conclusive results from the study are presented in four broad subject areas: (1) physical structure of pine stands, (2) pine tree mortality, (3) susceptibility of pine trees to bark beetles, and (4) susceptibility of pine stands to bark beetles. Some results are compared with corresponding ones obtained in the initial testing of the rating system at the Blacks Mountain Experimental Forest in northeastern California from 1937 to 1943.

Stands sampled by the Montana plots exhibited these average characteristics: composition, ponderosa pine 91 percent (vs. 66 percent at Blacks Mountain), nine percent Douglas-fir, larch, and lodgepole pine; pine stand density, 16,800 board feet per acre (12,200 board feet at Blacks Mountain), with a range on separate plots of from 9,990 to 25,200 board feet per acre; pine age classes, 96.1 percent of the total pine volume in mature (Keen's age class 3) or overmature (age class 4) trees; and pine growth rates, average radial growth of pine tree boles for the 10-year period ending in 1952, 0.43 inches for risk 1 trees; 0.31 inches for risk 2 trees; and 0.18 inches for risk 3 and risk 4 trees together. Risk 1, 2, 3, and 4 trees in pine stands of the Pacific Coast States are those whose susceptibility to lethal attacks by the western pine beetle varies from very low to very high, respectively.

The death of 205 risk-rated ponderosa pine trees on the Montana plots was caused by (1) windstorms, 59.1 percent; (2) the western pine beetle, 27.5 percent; (3) unknown factors, 5.1 percent; (4) lightning, 4.6 percent; and (5) other cambium-feeding insects, principally Ips and Melanophila spp., 3.7 percent. Nearly one-half of the wind-caused tree killing was recorded on three plots from two storms.

The 64 ponderosa pine trees killed by the western pine beetle contained 55,650 board feet. None of this volume was in risk 1 trees, 17.4 percent was in risk 2 trees, 26.5 percent was in risk 3 trees, and 56.1 percent was in risk 4 trees. On the basis of these meager data, about 83 of every 100 trees killed by the beetle were high risk trees, risk 3 and risk 4 trees of the rating system. In the 1937-1943 tests at Blacks Mountain, 84 of every 100 trees killed by the same beetle were high risk trees.

Susceptibility of ponderosa pine stands to depletion by the pine bark beetle was judged on the percentage of the total pine volume contained in high risk trees. The mean percentage of the high risk tree volume on all plots in Montana was 19.9, that at Blacks Mountain, 21.3. This indicated that stands in both areas generally exhibited a high degree of susceptibility to tree killing from attacks by the beetle. The percentage of high risk volume on individual plots in Montana varied from 2.6 (very low stand susceptibility) to 39.0 (very high susceptibility).

The mean volume of risk-rated trees was 777 board feet (865 board feet at Blacks Mountain). Risk 1 trees in Montana, and at Blacks Mountain in parentheses, averaged 512 (706) board feet; risk 2 trees, 770 (1,161) board feet; risk 3 trees, 1,033 (1,240) board feet; and risk 4 trees, 1,063 (1,219) board feet.

The slow accumulation of beetle-killed pine trees has caused an unforeseen delay in achieving the study objectives. The study is therefore being extended to provide additional experimental evidence upon which to base significant conclusions. This must be done before meaningful recommendations can be made for using the risk rating system as a device for controlling the western pine beetle in the northern Rockies.

The purpose of the report is to present to the project's workers, supervisors, and cooperators (1) the more significant results achieved to date and (2) an overall evaluation of the progress that has been made toward attaining the study objectives.

A PROGRESS REPORT OF A STUDY ON THE SUSCEPTIBILITY OF OLD-GROWTH PONDEROSA PINE IN MONTANA TO BARK BEETLE ATTACKS

(Line Project FS-2-e1-1-INT)

INTRODUCTION

The western pine beetle (Dendroctonus brevicomis Lec.)(Coleoptera: Scolytidae) has killed an average of one billion board feet of ponderosa pine annually during the past 50 years in California, Oregon, Washington, Idaho, and Montana. The killing in a single year has reached as high as 3.5 billion board feet (11). In recent years, however, the loss of pine timber from beetle infestations has been greatly reduced in the Pacific Coast States. This has been accomplished by making sanitation-salvage cuttings in pine stands where beetle infestations were unusually persistent or where the threat of destructive infestations was great. These selection cuttings were devised in California in 1937 to harvest the beetle-susceptible pine trees from the stands, trees that normally account for an average of from 15 to 30 percent of the total volume in the pine stands. The cuttings, and the Ponderosa Pine Risk Rating System used to identify the susceptible trees, have been described by Salman and Bongberg (9).

Extensive stands of commercially valuable ponderosa pine grow throughout the northern Rocky Mountains of the western United States. These, too, are subject to damage and depletion by the western pine beetle. Controlling beetle infestations in this region by sanitation-salvage cuttings, however, has never been recommended pending a test of their effectiveness. Certain peculiarities in pine stand structure and beetle behavior were pointed out by Johnson (2) that suggested the need for testing the cuttings, as well as the Ponderosa Pine Risk Rating System, to evaluate their adaptability in the northern Rockies.

A study was begun in Montana in 1948 by the Coeur d'Alene forest insect laboratory of the U. S. Department of Agriculture to determine whether sanitation-salvage cuttings could be used for effective beetle control in the northern Rockies. Specifically, the study set out to determine (1) whether there was any apparent tree selection by the western pine beetle or its principal associate in this region, the mountain pine beetle (D. monticolae Hopk.), (2) whether the selected trees could be identified by the risk rating system, and (3) whether the removal of these trees from the stands by sanitation-salvage cuttings could prevent the buildup of beetle infestations in them.

These objectives have not yet been fully attained. The study has progressed, however, to the point where some meaningful results have appeared. Presented here are those which (1) describe the physical structure of old-growth ponderosa pine stands, (2) report the nature and extent of pine tree mortality accrued thus far, and (3) analyze the distribution of both dead and living pine trees according to their rated risk or presumed susceptibility to attack by the western pine beetle. Results from Montana are compared wherever possible with corresponding results obtained during a test of the risk rating system at the Blacks Mountain Experimental Forest in northeastern California between 1938 and 1947.

HISTORICAL BACKGROUND

It is doubtful if any forest insect pest has been studied more diligently than the western pine beetle. The findings of many dedicated workers were excellently summarized by Keen in 1960 (4). Person (8) was one of the first to investigate what appeared to be a demonstrated preference of the beetle for certain brood trees. Succeeding studies provoked discussion as to whether the beetle arbitrarily chose to attack certain trees, or whether they attacked indiscriminantly, eventually succeeding only in certain trees (U2). Although these opposing points of view have not been resolved experimentally, workers generally agree that ponderosa pine trees with certain easily-recognized external characteristics succumb from beetle attacks more often than do trees without these characteristics.

Dunning was the first to make use of this apparent beetle trait by incorporating it into his ponderosa pine tree classification (1). In it trees with certain age, dominance, and crown characteristics were recognized as dying more often from attacks by the beetle than trees with other characteristics. The ponderosa pine tree classification later developed by Keen (3) attempted to identify more precisely the kinds of trees most frequently attacked by the western pine beetle. This classification proved adequate for long-term predictions of tree susceptibility to beetle attacks, but it failed to reflect current changes in tree susceptibility brought about by fast-moving changes in the environment that produced corresponding quick changes in tree vigor.

The need for evaluating the current susceptibility of pine trees caused by rapid changes in their ecosystem led Salman and Bongberg to devise the Ponderosa Pine Risk Rating System in 1937 (9). Extensively tested at the Blacks Mountain Experimental Forest in northeastern California, the system has since proven to be an effective tool for identifying beetle susceptible trees in interior type ponderosa pine stands--Type 237 of the Society of American Foresters (10)--in northeastern California and in the eastern parts of Oregon and Washington. The differences between the risk rating system and the Keen classification are often confusing to foresters. These differences were described by Keen and Salman in 1942 (5).

METHODS OF STUDY

The study was restricted to merchantable, old-growth ponderosa pine stands west of the Continental Divide in Montana. The Ponderosa Pine Risk Rating System is not meaningful east of the Divide because of the absence there of the western pine beetle.

The bases for information on the physical structure of old-growth ponderosa pine stands were the measurements and descriptions of pine trees on 35 plots totalling 553 acres in area (table 6.). Seventeen plots with an aggregate area of 155 acres were established throughout western Montana, most of them in 1952. The remaining 18 plots with a total area of 398 acres were set up from 1957 to 1959 on the Piquett Creek Experimental Area near Darby, Montana. All trees over 11.1 inches in diameter on the plots were measured for later volume computation. In addition, ponderosa pine trees were tagged with serial numbers, risk-rated (Appendix), and classified by age and tree vigor by the Keen tree classification. Altogether, 11,946 ponderosa pine trees were measured and classified on the 35 plots and their total estimated gross volume was 9,276,360 board feet, Scribner log rule.

Part of the stand structure information presented here pertaining to radial growth rates of risk-rated ponderosa pine trees is the work of Mr. John S. Spencer, a graduate student during the 1952-1953 academic year at Montana State University. His investigation was made on some of the plots used in this study under a cooperative agreement between the University and the Department's forest insect laboratory at Coeur d'Alene.

Mortality of risk-rated ponderosa pine trees was measured annually. Causal factors were determined prior to 1952 from gross external tree symptoms supplemented by cambial examinations of the basal bole section of the standing dead trees. Beginning in 1952, the dead trees were felled and the cambium examinations were made in a systematic manner along the entire bole length.

RESULTS

Physical Structure Of Pine Stands

The study disclosed certain similarities between the structure of old-growth ponderosa pine stands in Montana and those on the Blacks Mountain Experimental Forest in northeastern California where the risk rating system was developed. Stands in both localities easily fitted the description of interior ponderosa pine.

Stand Composition

Composition of the overstory stands on the plots in Montana, averaged 91 percent ponderosa pine, as compared to 66 percent at Blacks Mountain (tables 6 and 7, Appendix). Tree species other than ponderosa pine varied on the Montana plots from an average of zero to 35.3 percent of the total measured stand volume. Collectively, plots in the western Montana series averaged 7.3 percent of the total stand volume in non-pine species while those at Piquett Creek averaged 11.3 percent.

The understory on most of the Montana study plots showed a dearth of ponderosa pine reproduction, saplings, and poles. On the other hand, Douglas-fir reproduction, saplings, and poles were so abundant in the understory of many plot stands that further occupancy of the sites by ponderosa pine appeared to be threatened.

Pine Stand Density

Pine stands represented by the Montana plots were comparatively dense in terms of board-foot volume per acre. The mean ponderosa pine volume was about 16,800 board feet per acre in trees over 11.1 inches in diameter as compared to the mean of approximately 12,200 board feet plus 4,520 board feet of Jeffrey pine on the Blacks Mountain Experimental Forest in California (7). The mean volume on separate plots in Montana varied from about 9,990 board feet to 25,200 board feet per acre (figure 1A, tables 7 and 8). This wide density range, even in contiguous, small localities, is a frequently observed characteristic of old-growth ponderosa pine stands.

Pine Age Classes

Visual criteria of tree age used in selecting old-growth ponderosa pine sites for study plots in western Montana proved reasonably accurate when field measurements of tree age were summarized. Applying the Ponderosa Pine Tree Classification to all plot trees 11.1 inches in diameter and over disclosed that 96.1 percent of them were mature, class 3, or overmature, class 4 (figure 1B).

Only slight differences existed between the distribution of pine tree age classes in the plots scattered throughout western Montana and those at Piquett Creek (table 1).

Both sets of plots reveal what appears to be an absence of young, age class 1, and immature, age class 2, trees. Trees in these age classes were observed to be relatively scarce. Most of those observed on the plots were below the minimum diameter of 11.1 inches used in the study.

Table 1.--Distribution by Keen age classes of total ponderosa pine tree volume on plots

Keen age class	Average percentage of pine volume	
	Western Montana plots	Piquett Creek plots
1 - Young	0.3	0
2 - Immature	6.6	2.6
3 - Mature	27.0	23.3
4 - Overmature	66.1	74.1
	100.0	100.0

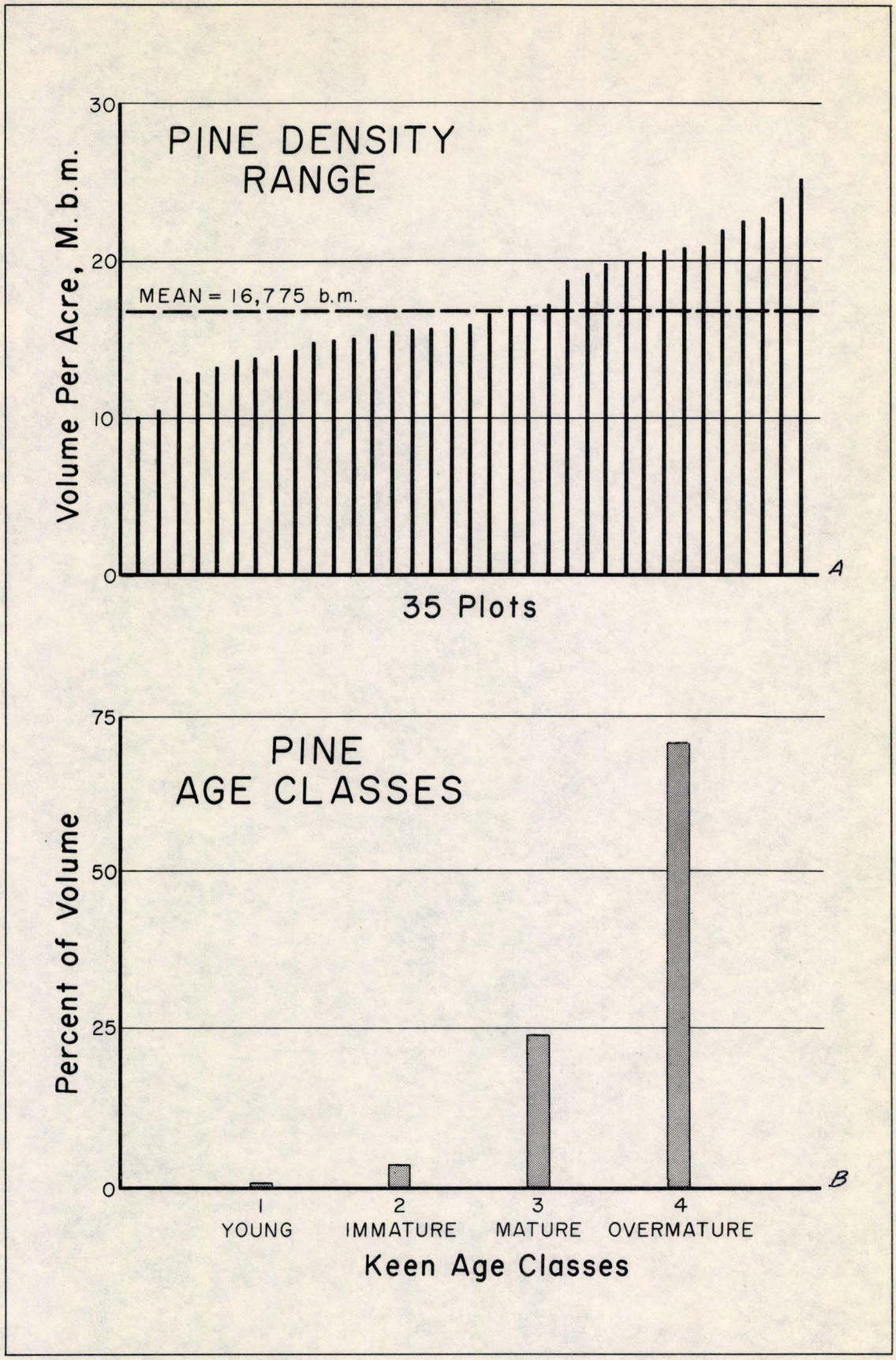

Figure 1.--Some characteristics of old-growth ponderosa pine stands in Montana.

Age classes were not directly related to vigor, and hence risk ratings of individual trees. The best that can be said after examining plot data is that there is a greater preponderance of low risk trees in the young and immature age classes, and that this is replaced in the mature and overmature age classes by an increasing proportion of high risk trees. Said another way, young trees generally present a lower risk of beetle attack and old trees a greater risk, as demonstrated in the following tabulation:

Keen's age classes	Percentage of pine volume on plots	
	Low risk trees (Risk 1 and 2)	High risk trees (Risk 3 and 4)
1 - Young	100.0	0
2 - Immature	98.7	1.3
3 - Mature	91.1	8.9
4 - Overmature	75.3	24.7

Pine Growth Rates

Spencer (U4) established significant correlations between the rate of radial growth in the boles of trees in different risk ratings:

Risk rating	Average radial growth in inches (last 10 years, cumulative)
1 - Very low	0.43
2 - Moderate	0.31
3 - High 4 - Very high	0.18

From the above it may be seen that the rate of growth was inversely proportional to the risk rating of the trees.

Site Quality

Site quality for most of the plots was IV, based upon Meyer's (6) site-quality classification for ponderosa pine lands. This means that the average height of mature pine trees was 110 feet.

Pine Tree Mortality

Various factors caused the death of 205 ponderosa pine trees on 16 plots in western Montana between 1948 and 1960 and of 40 trees on 18 plots on the Piquett Creek Experimental Area between 1958 and 1960. Death of the 245 trees with an aggregate gross volume of 202,000 board feet was caused by (1) uprooting and a lesser amount of bole breakage by wind, (2) attacks by the western pine beetle or, occasionally, by the mountain pine beetle, (3) lightning, (4) attacks by other cambium-feeding insects, and (5) unknown factors, in that order (table 2).

Two windstorms in 1955 caused 71 percent of the tree killing from this source and all of it was restricted to three of the 35 plots. The balance of the wind-caused tree killing was more uniformly distributed at more constant intervals during the period of study.

Dendroctonus bark beetles killed 64 pine trees--58 by D. brevicomis and six by D. monticolae. The pattern of killing showed a low but consistent annual rate indicative of endemic infestations that prevailed during the initial part of the study period reported here. During this period the rate of killing by beetles on the Montana plots was about one-fifth that reported[1/] from 1938 to 1959 on the Blacks Mountain Experimental Forest in California:

	Mean annual rate of pine tree killing by Dendroctonus beetles	
	Western Montana 1952-1960	Blacks Mountain 1938-1959
Board feet per acre	19.	100.
Percentage of volume	0.121	0.608

The low infestation rate in Montana caused measurements of beetle-caused tree mortality to be accumulated slower than was anticipated in the study plan. An adequate number of measurements may be acquired by extending the study period beyond that originally planned.

The loss of pine trees from other insects such as Ips oregonis, I. emarginatus, and Melanophila sp., from unknown causes, or from lightning was negligible.

[1/] From information furnished by Charles B. Eaton, chief, Division of Forest Insect Research, Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

Table 2.--Amount and cause of cumulative ponderosa pine tree mortality

Causal agent	Pine tree mortality							
	Western Montana plots[1]		Piquett Creek plots[2]		All plots			
					Trees		Volume	
	No. of trees	Volume, bd. ft.	No. of trees	Volume, bd. ft.	Number	%	Bd. ft.	%
Windstorms	133	103,440	17	15,950	150	61.2	119,390	59.1
Bark beetles	44	32,700	20	22,950	64	26.1	55,650	27.5
Lightning	3	5,710	2	4,680	5	2.1	10,390	4.6
Other insects	15	8,220	1	980	16	6.5	9,200	3.7
Unknown	10	7,430	0	0	10	4.1	7,430	5.1
Totals	205	157,500	40	44,560	245	100.0	202,060	100.0

1/ Reporting period, 1948-1960.

2/ Reporting period, 1958-1960.

Lightning-struck ponderosa pine trees, however, are of some concern to the study. A few survive the experience, but most of them are heavily attacked the year they were struck or the year following by D. brevicomis. These trees apparently make ideal host material, for beetle broods bred in them greatly surpass in number those produced in living trees attacked by the beetle (figure 2). Lightning most frequently strikes the dominant, low vigor, and hence low risk, trees. If these trees were to be struck often enough in a given area, it is conceivable that they, instead of the high risk trees of the risk rating system, could temporarily become the favored breeding place for beetle populations.

Susceptibility Of Pine Trees To Bark Beetles

Dendroctonus beetles killed 64 ponderosa pine trees that had been risk-rated for periods of from one to 12 years before their death. No attempt was made to correlate the ratings of these trees with the period of time that had elapsed since they were made. Periodic rerating of plot trees is planned to determine the rate and nature of changes in risk. The study did reveal, however, that 78.1 percent of the beetle-killed trees were either risk 3 or risk 4, the so-called high risk categories of the rating system. Beetle-killed trees in these two ratings contained 82.6 percent of the volume of the 64 trees (table 3), whereas high risk trees made up an average of 19.9 percent of the living pine trees on the plots. This is equivalent to a mortality ratio of 4:1, an indication of a significant selection of high risk trees by the beetle.

The risk rating distribution of the comparatively small number of beetle-killed trees in Montana compares favorably with that of the initial 404 ponderosa pine trees killed by the western pine beetle at Blacks Mountain between 1936 and 1943. Bongberg (U1) reported that 78.8 percent of them, or 84.3 percent of their volume, were risk 3 or risk 4 (figure 3A). Thus it would appear that trees in these two ratings succumbed from beetle attacks in Montana to the same degree that they did in the California study. More evidence is needed in Montana, however, before this can be confirmed.

Figure 2.--(A) Ponderosa pine tree struck by lightning near the Piquett Creek Experimental Area, Montana; typically mature, dominant, and low risk. (B) Bole section of the same tree infested shortly afterward by the western pine beetle, showing heavy bark scaling by woodpeckers feeding on beetle larvae. (C) Pine beetle brood emergence holes average 460 per square foot of bark surface on this lightning-struck ponderosa pine tree on the Overwhich Creek risk plot. Emerging beetles here were 7-10 times as numerous as from infested trees not previously struck by lightning. (INT. Msla. 1863, 1864, 1867.)

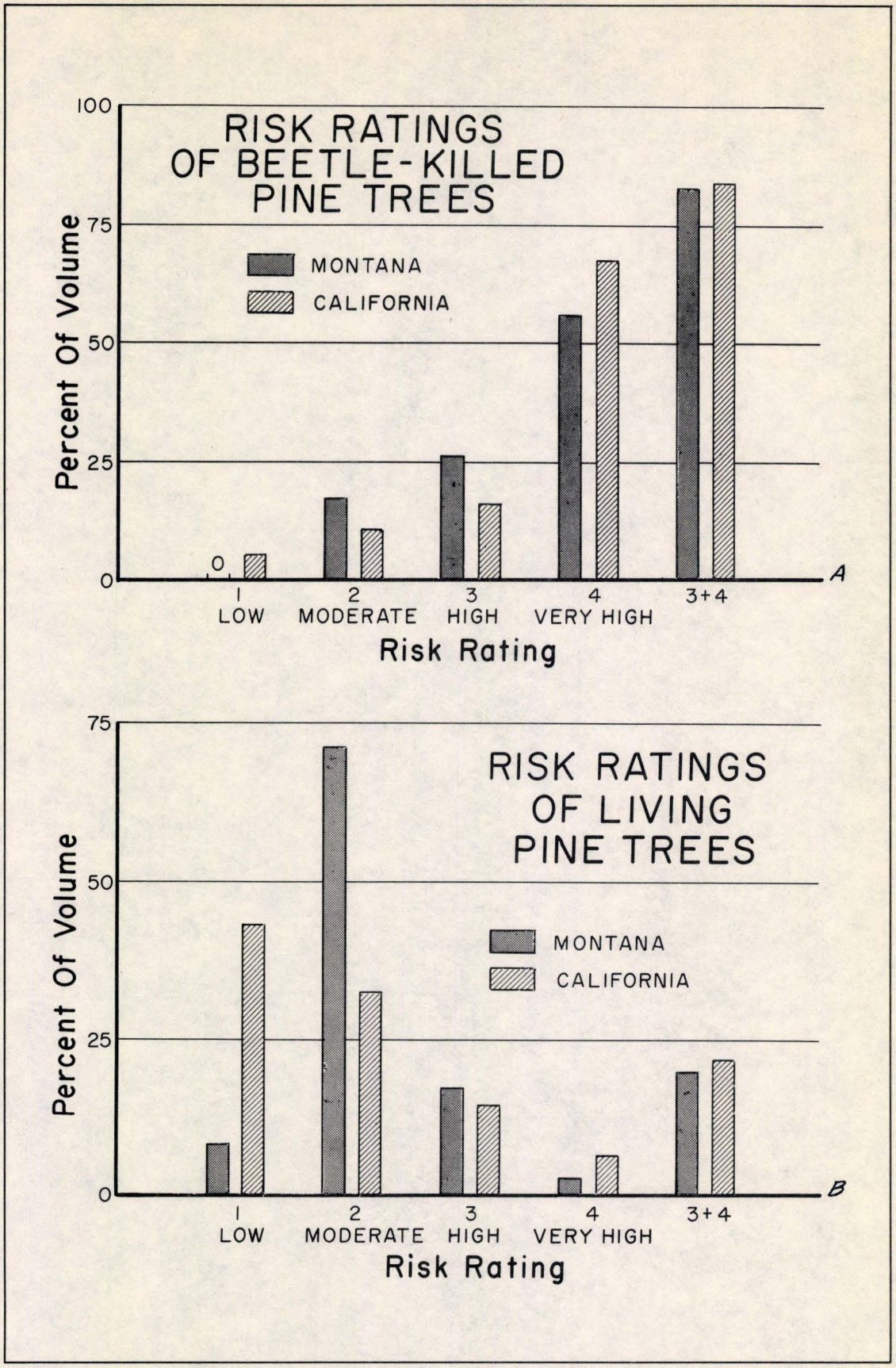

Figure 3.--Mean distribution of risk-rated ponderosa pine trees on plots in Montana and compartments at Blacks Mountain Experimental Forest, California.

Table 3.--Risk rating of ponderosa pine trees killed by bark beetles

Area	Risk rating	Pine trees killed			
		Trees		Volume	
		Number	Percent	Bd. ft.	Percent
Western Montana	1	0	0	0	0
(16 plots, 1948	2	9	20.5	5,850	17.9
to 1960)	3	14	31.8	6,570	20.1
	4	21	47.7	20,280	62.0
	3 + 4	35	79.5	26,850	82.1
		44	100.0	32,700	100.0
Piquett Creek	1	0	0	0	0
Experimental Area	2	5	25.0	3,840	16.7
(18 plots, 1958	3	6	30.0	8,160	35.6
to 1960)	4	9	45.0	10,950	47.7
	3 + 4	15	75.0	19,110	83.3
		20	100.0	22,950	100.0
Blacks Mountain	1	34	8.4	25,380	5.3
Experimental Forest	2	52	12.9	51,010	10.5
(1936 to 1943) [1/]	3	65	16.1	81,600	16.8
	4	253	62.6	326,650	67.4
	3 + 4	318	78.7	408,250	84.2
		404	100.0	484,640	100.0

[1/] Bongberg (U1), table 1.

Susceptibility Of Pine Stands To Bark Beetles

Occurrence Of High Risk Trees

In addition to knowing what trees are most susceptible to attack by by the western pine beetle, foresters often are interested in learning which stands are most likely to be depleted from beetle infestations. These stands can then be given priority in management plans to harvest the timber before serious losses happen, to take action to control infestations that already are active, or to prevent those that are likely to appear. Means of measuring the susceptibility of pine stands to beetle attack have been used successfully in the Pacific Coast States for the past 25 years. In 1937, Salman and Johnson (U3) hypothesized that the hazard of ponderosa pine stands from, or their susceptibility to, attack by the western pine beetle could be measured in part by the percentage of present pine volume occurring as high-risk trees. This was part of the method used for an inventory of bark beetle hazard of 2,452,000 net timbered acres of ponderosa pine stands in northeastern California begun in 1937 and completed in 1940 (7).

The following arbitrary classification of stand susceptibility to beetles was used by the California inventory:

Average percentage of high risk trees	Relative susceptibility of stands to beetle attack
0 - 5	VERY LOW. Light, sporadic infestations should cause no stand depletion.
6 - 10	LOW. Infrequent infestations may cause slight depletion.
11 - 18	MODERATE. Frequent, relatively severe infestations expected to cause moderate depletion.
19 - 26	HIGH. Heavy depletion expected from sustained or frequent infestations.
Over 26	VERY HIGH. Complete depletion threatened from sustained or frequent severe infestations.

The degree of susceptibility described in the right-hand column may or may not apply in Montana. Earlier it was stated that beetle-caused losses in Montana were considerably lower than comparable losses in northeastern California. For given high risk percentages, losses in Montana may be less than indicated by the classification.

High risk trees accounted for 15.4 percent of the total pine volume on the western Montana plots. Similar percentages at Piquett Creek and Blacks Mountain were 21.8 and 21.3, respectively (table 4). According to the above stand susceptibility classification, pine stands represented by the western Montana plots were found to be moderately susceptible to beetle attack, those at Piquett Creek and Blacks Mountain highly susceptible. Individual plots, however, varied from very low susceptibility (2.6 percent) to very high susceptibility (39.0 percent of the stand in risk 3 and risk 4 trees).

Risk 2 trees were the most abundant on the plots in Montana (tables 9 and 10), whereas most of the trees at Blacks Mountain were rated risk 1 (figure 3B). This could be because of differences in interpretation of the risk rating system by field personnel, or because of valid differences in the stand structure in the two localities. The latter view is favored here, since there is marked similarity in the percentage of high risk volumes between the two areas. In the final reckoning, the abundance of high risk trees is the most important part of the risk rating process. These are the trees that bark beetles may eventually kill; these are the trees that sanitation-salvage cuttings will take out of the stands if the risk rating system becomes an effective forest namagement tool in Montana.

Mean Volume Of Risk-Rated Pine Trees

Resistance encountered in promoting pioneer sanitation-salvage cuttings in northeastern California and southern Oregon was based in part on the belief by some logging contractors and superintendents that risk 3 and risk 4 trees of the risk rating system were sub-marginal in size and quality. They felt that this was one of the factors that would make the cuttings unprofitable. Experimental evidence at Blacks Mountain supported subsequent timber appraisals in proving that this was not the case. High risk trees actually were larger than the average pine tree in the stands. Observations from the first commercial cuttings showed, too, that high risk trees were not poorer in quality than most of the trees in the stand.

These findings were substantiated by the risk rating study in Montana. High risk trees proved to be larger than the average trees in the plot stands in terms of board-foot volume. The mean volume of trees in the four risk ratings shown in Table 5 for the Montana plots and for the compartments studied from 1936 to 1943 at Blacks Mountain revealed that the California trees were slightly greater in mean volume, but that the general pattern of per-tree volumes by risk ratings is essentially the same.

Table 4.--Mean volume per acre of living, risk-rated ponderosa pine trees

Risk rating	Montana				California	
	Western Montana plots		Piquett Creek plots		Blacks Mountain Exper. Forest	
	Bd. ft.	Percent	Bd. ft.	Percent	Bd. ft.	Percent [1]
1 - Low	2,780	15.6	895	5.4	5,291	46.2
2 - Moderate	12,271	69.0	11,910	72.8	3,722	32.5
3 - High	2,402	13.5	3,044	18.5	1,661	14.5
4 - Very high	329	1.9	537	3.3	779	6.8
3 + 4	2,731	15.4	3,581	21.8	2,440	21.3
Totals	17,782	100.0	16,386	100.0	11,453	100.0
Basis: no./trees	4,239		7,707		353,895	

[1] Percentages from Miller, Salman, and Johnson (7), Part II, page 202.

Table 5.--Mean volume of risk-rated ponderosa pine trees in Montana and California

Risk rating	Board-foot volume per tree		
	Montana		California
	W. Montana plots	Piquett Cr. plots	Blacks Mtn. compartments
1	422	690	706
2	696	804	1,161
3	901	1,081	1,240
4	690	1,221	1,219
[1]3 + 4	869	1,100	1,230
All trees	650	846	865

[1] High risk trees normally harvested in sanitation-salvage cuttings.

DISCUSSION

At this point there is reason to expect that objectives of the study will be attained without encountering any serious obstacles save one. This one may well be the continued slow accrual of beetle-killed trees, trees which the study must have to test the risk rating system. Because of this unforeseen development, the period of investigation must necessarily be extended until an appropriate amount of data on beetle-killed trees is at hand.

Based upon the results to date--some reasonably conclusive, some only provisional--there is further reason to suspect that the Ponderosa Pine Risk Rating System may adequately assess the degrees of susceptibility or resistance of old-growth ponderosa pine trees to attacks of the western pine beetle in the northern Rockies. There are several reasons for this viewpoint:

1. Striking similarity between the structure of pine stands in Montana and that of stands used for the initial tests of the rating system in northeastern California.

2. Further similarity in visible symptoms of tree vigor between the two study areas.

3. Ease of applying the rating system unmodified in Montana because of the similarities in 1 and 2.

4. Consistent preferential selection of high risk trees by the pine beetle in Montana, to a degree comparable to the selection demonstrated at the Blacks Mountain Experimental Forest where the rating system was evolved.

5. Distribution of high risk trees in Montana ponderosa pine stands that closely approximates that of the stands at Blacks Mountain.

Despite results to date, a sound evaluation of the risk rating system's worth in the northern Rockies will not be forthcoming without further experimental evidence. Until larger populations of bark beetles exert greater pressures on these stands there is no basis for recommending that the Ponderosa Pine Risk Rating System can be used as a device for controlling the western pine beetle in this region.

FUTURE PLANS

The rate at which beetle-killed trees have appeared thus far makes it advisable to continue annual or biennial measurements of mortality until more significant data are obtained. The rate of progress will depend upon the extent of future beetle populations in the area.

Infestation patterns of the western pine beetle and related cambium-feeding insects have been summarized from field analyses of the boles of infested ponderosa pine trees. Results will be described in a technical publication or in a separate progress report.

A photographic guide to aid in recognizing risk-rated ponderosa pine trees in Montana awaits completion of additional photography.

A final aspect of the current study plan to be completed is a re-rating of ponderosa pine trees on the plots. This should shed some light on the permanence of risk ratings in the northern Rockies and on some of the more obvious factors affecting it.

Certain aspects of other bark beetle studies now being planned for the northern Rocky Mountains may supplement results from the present study of ponderosa pine risk rating. Among them are:

1. Biology and behavior of the western pine beetle and the mountain pine beetle in immature and mature ponderosa pine.

2. Effect of root rots on the vigor of ponderosa pine trees.

3. Use of oleoresin pressure measurements and other possible devices for determining the relative vigor of old-growth ponderosa pine trees.

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[1] Copies of the reports listed here are on file at the Intermountain Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, Federal Building, Missoula, Montana. Mr. Spencer's thesis is filed in the library of Montana State University, Missoula.

APPENDIX

DESCRIPTIONS OF PONDEROSA PINE RISK RATING[1/]

RISK I. LOW RISK (Trees seldom killed by the western pine beetle)

Crowns full foliaged, healthy appearing, no weakened portions. Foliage of healthy appearance. Needles usually long and coarse, color good dark green. Practically all twigs with normal foliage complement.

RISK II. MODERATE RISK (Trees occasionally killed by beetles)

Crowns fair to moderately healthy, imperfect in spots. Foliage mostly healthy. Needles average in length or longer, color fair to good. Some twigs or branches may lack foliage, but such injury should not be localized to form definite "weak" spots in crown.

RISK III. HIGH RISK (Trees frequently killed by beetles)

Crowns fair to poor in health, somewhat ragged or thin in portions, some localized weakened portions usually present. Foliage in parts of crown thin, bunchy, or unhealthy. Needles average in length or shorter, color fair to poor. Some to many twigs or branches lacking foliage, some to many twigs or branches fading or dead.

RISK IV. VERY HIGH RISK (Trees most frequently killed by beetles)

Crowns in poor condition, ragged or thin, often showing evidence of active insect infestations in upper portions. Foliage thin or bunchy, needles short or sparse, color poor. Twigs and brances dead or dying. Portions of crown definitely weakened. Active topkilling or partially infested crowns often present.

1/ Adapted from Salman and Bongberg (9); see also Keen and Salman (5).

PENALTY SYSTEM OF RATING TREE RISK

Symptoms of poor tree health	Penalty: Moderate condition	Penalty: Bad condition
CROWN CONDITION (Score 0 to 4)		
1. Weak spots in crown	0	1
2. Scattered, scraggly, irregular crown	1	2
3. Thin open crown throughout	1	2
4. Thin open top, dense below	2	4
5. General poor vigor, unhealthy	2	4
NEEDLE CONDITION (Score 0 to 4)		
1. Tufts at ends of long bare branches	0	1
2. Complement below average	0	1
3. Length below average	1	2
4. Short needles in top, longer below	2	4
5. Fading or off color	2	4
WEAKNESS OR INJURY (Score 0 to 8)		
1. Mistletoe or witch's broom	0	1
2. Old spike not active	0	1
3. Broken top, not dying below	0	1
4. Fire scar	0	1
5. Dying lateral twigs	2	4
6. Dying tip of terminal	1	2
7. Lightning strike	3	6
8. Active top killing	4	8
9. Active infestation by *Dendroctonus brevicomis*, *D. monticolae*, *D. valens*, and other species	6	8

RELATION TO PONDEROSA PINE RISK RATING SYSTEM:

Risk rating	Penalty score
1	0
2	1-2 inclusive
3	3-5 inclusive
4	6 and over

Original by F. P. Keen, 1941.
Revised at Senaca (Oregon) Conference, August 1948.

Table 6.--Plots used in studying the Ponderosa Pine Risk Rating System in Montana from 1948 to 1960

Plot	Land owner[1]	Timbered acreage	Year establ.	Location	
				County	Land subdivision
		WESTERN MONTANA SERIES			
Loon Lake	Private 3	5.4	1948	Lincoln	S20-21, T27N, R28W
Rexford	U. S. 6	5.0	1948	Lincoln	S16, T36N, R28W
Lincoln AFP	Private 1	12.0	1949	L. and C.	S6, T14N, R8W
Lit. Bitterroot R.	Private 2	10.0	1951	Flathead	S30, T26N, R24W
Bear Cr. Saddle	U. S. 4	8.4	1952	Ravalli	S15, T1N, R20W
Overwhich Creek	U. S. 4	10.0	1952	Ravalli	S11-14, T2S, R22W
Fish Creek Forks	Private 1	10.0	1952	Mineral	S35, T14N, R25W
McCrea Park	Private 1				
	U. S. 7	7.0	1952	Mineral	S35, T14N, R25W
Longpre Cabins	Private 1	8.9	1952	Mineral	S36, T14N, R25W
Fishtrap Creek	Private 1	10.0	1952	Sanders	S27, T23N, R27W
Little Thompson R.	Private 1	10.0	1952	Sanders	S1, T22n, R27W
N. Fk. Lit. Thomps.	Private 1	10.0	1952	Sanders	S9, T22N, R26W
Pleasant Valley	Private 1	10.0	1952	Flathead	S19, T28N, R25W
Little Ranch	Private 1	10.0	1952	Flathead	S25, T28N, R26W
Lost Prairie	Private 1	10.0	1952	Flathead	S31, T28N, R26W
Lake McGregor	Private 1	8.5	1952	Flathead	S9, T26N, R25W
Lincoln FS	U. S. 5	9.7	1952	L. and C.	S19, T14N, R8W
Subtotal		154.9			

Table 6.--Plots used in studying . . . from 1948 to 1960 (continued)

Plot		Land owner	Timbered acreage	Year establ.	Location	
					County	Land subdivision
			PIQUETT CREEK SERIES			
Control:	B	U. S. 4	22.0	1959	Ravalli	S10, T1N, R21W
	D	U. S. 4	22.0	1959	Ravalli	S9, T1N, R21W
	G	U. S. 4	22.6	1959	Ravalli	S10, T1N, R21W
	J	U. S. 4	22.6	1959	Ravalli	S9-10, T1N, R21W
	O	U. S. 4	15.8	1959	Ravalli	S10-15, T1N, R21W
	Q	U. S. 4	22.5	1959	Ravalli	S9-16, T1N, R21W
Treatment I:	C	U. S. 4	22.7	1958	Ravalli	S9-10, T1N, R21W
	F	U. S. 4	24.0	1957	Ravalli	S10, T1N, R21W
	H	U. S. 4	22.2	1957	Ravalli	S9-10, T1N, R21W
	K	U. S. 4	22.5	1957	Ravalli	S10, T1N, R21W
	L	U. S. 4	21.3	1957	Ravalli	S10, T1N, R21W
	P	U. S. 4	22.5	1958	Ravalli	S9-16, T1N, R21W
Treatment II.	A	U. S. 4	22.4	1957	Ravalli	S10, T1N, R21W
	E	U. S. 4	22.2	1957	Ravalli	S9-10, T1N, R21W
	I	U. S. 4	21.9	1958	Ravalli	S9, T1N, R21W
	M	U. S. 4	23.7	1958	Ravalli	S10, T1N, R21W
	N	U. S. 4	22.5	1958	Ravalli	S10-15, T1N, R21W
	R	U. S. 4	22.5	1958	Ravalli	S9, T1N, R21W
Subtotal			397.9			
Total			552.8			

[1] Land ownership symbols:
Private 1 - Anaconda Forest Products Company, Bonner
Private 2 - Glacier Park Company, Somers
Private 3 - J. Neils Lumber Company, Libby
U. S. 4 - Bitterroot National Forest, Hamilton
5 - Helena National Forest, Helena
6 - Kootenai National Forest, Libby
7 - Lolo National Forest, Missoula

Table 7.--Average plot stand per acre, trees 11.1 inches or more in diameter (Western Montana plots)

Plot	Ponderosa pine		Other tree species			All species	
	No. of trees	Volume, bd. ft.	Species	No. of trees	Volume, bd. ft.	No. of trees	Volume, bd. ft.
Loon Lake	27.7	16,722				27.7	16,722
Rexford	19.4	15,574				19.4	15,574
Lincoln AFP	17.3	9,991	DF[1/]	15.9	5,443	33.2	15,434
Little Bitterroot R.	28.9	15,800	DF	5.5	2,250	34.4	18,050
Bear Cr. Saddle	20.6	22,765	DF	4.1	1,083	24.7	23,848
Overwhich Creek	25.1	25,198	LP-DF	0.5	32	25.6	25,230
Fish Cr. Forks	22.4	13,636	L-DF	2.1	856	24.5	14,492
McCrea Park	17.1	20,590	L-DF	7.0	5,142	24.1	25,732
Longpre Cabins	37.3	12,550	DF-L	5.5	744	42.8	13,294
Fishtrap Creek	33.8	14,353	DF	2.3	646	36.1	14,999
Little Thompson	26.5	14,852	LP	5.5	622	32.0	15,474
N. Fk. Lit. Thompson	33.6	15,616	L-LP-DF	6.5	1,702	40.1	17,318
Pleasant Valley	36.6	24,098	L	0.4	263	37.0	24,361
Little Ranch	27.9	18,839	LP-L	2.4	536	30.3	19,375
Lost Prairie	30.7	22,636	L-LP	0.7	183	31.4	22,819
Lake McGregor	36.1	19,837	L-DF	8.8	4,155	44.9	23,992
Lincoln FS	20.1	20,683	LP	1.1	73	21.2	20,756
Means	27.3	17,783		4.0	1,396	31.3	19,179

[1/] Species listed in order of decreasing importance. Symbols: DF, Douglas-fir; L, western larch; LP, lodgepole pine.

Table 8.--Average plot stand per acre, trees 12 inches or more in diameter (Piquett Creek Experimental Area)

Plot		Ponderosa pine		Other tree species			All species	
		No. of trees	Volume, bd. ft.	Species	No. of trees	Volume, bd. ft.	No. of trees	Volume, bd. ft.
Control:	B	19.7	17,078	DF[1]				
	D	16.2	13,113					
	G	20.8	14,888					
	J	26.1	22,082					
	O	14.7	15,354					
	Q	21.1	15,749					
Treatment I:	C	17.5	12,739	DF	8.0	1,378	25.5	14,117
	F	20.2	17,246	DF	6.1	1,159	26.3	18,405
	H	18.0	15,046	DF	5.8	1,723	23.8	16,769
	K	24.2	15,429	DF	12.1	2,137	36.3	17,566
	L	18.5	20,031	DF	12.5	2,375	31.0	22,406
	P	15.3	13,990	DF	15.7	3,948	31.0	17,938
Treatment II:	A	15.2	10,389	DF	15.0	2,533	30.2	12,922
	E	23.1	21,102	DF	9.9	2,236	33.0	23,338
	I	19.4	16,666	DF	7.8	1,869	27.2	18,535
	M	21.9	19,161	DF	6.9	1,556	28.8	20,717
	N	17.4	20,834	DF	6.8	1,215	24.2	22,049
	R	17.5	13,716	DF	13.5	2,956	31.0	16,672
Means		19.3	16,386	DF	10.0	2,082	29.3	18,468

[1] Merchantable Douglas-fir cut and utilized before control plots were established.

Table 9.--Distribution of trees and tree volumes by risk ratings (Western Montana plots)

Plot	Unit of measure	Risk ratings 1	2	3	4	Totals
Loon Lake	Trees	78	61	8	2	149
	Bd. ft.	32,950	46,290	10,000	560	89,800
Rexford	Trees	6	68	17	6	97
	Bd. ft.	4,580	58,590	10,750	3,950	77,870
Lincoln AFP	Trees	30	169	8	1	208
	Bd. ft.	17,920	98,880	2,760	330	119,890
Lit. Bitterroot R.	Trees	48	179	48	14	289
	Bd. ft.	15,130	104,230	32,220	6,420	158,000
Bear Cr. Saddle	Trees	13	118	39	4	174
	Bd. ft.	7,730	135,240	46,810	2,360	192,140
Overwhich Creek	Trees	77	138	30	6	251
	Bd. ft.	73,180	151,500	25,740	1,560	251,980
Fish Creek Forks	Trees	87	110	23	4	224
	Bd. ft.	14,670	87,200	30,460	4,030	136,360
McCrea Park	Trees	19	83	16	2	120
	Bd. ft.	37,920	90,530	14,490	1,190	144,130
Longpre Cabins	Trees	89	210	27	8	334
	Bd. ft.	17,340	79,020	12,930	3,030	112,320
Fishtrap Creek	Trees	145	164	27	2	338
	Bd. ft.	21,100	96,930	24,380	1,120	143,530
Little Thompson R.	Trees	47	194	22	2	265
	Bd. ft.	13,690	114,160	20,140	530	148,520

Table 9.--Distribution of trees and tree volumes by risk ratings (Western Montana plots) (continued)

Plot	Unit of measure	Risk ratings 1	2	3	4	Totals
N. Fk. Lit. Thomps.	Trees	77	206	44	9	336
	Bd. ft.	13,100	108,970	27,210	6,880	156,160
Pleasant Valley	Trees	40	299	22	5	366
	Bd. ft.	27,220	197,870	13,830	2,060	240,980
Little Ranch	Trees	43	200	30	6	279
	Bd. ft.	19,320	125,890	30,570	12,610	188,390
Lost Prairie	Trees	109	179	17	2	307
	Bd. ft.	52,090	143,690	26,310	4,270	226,360
Lake McGregor	Trees	57	230	18	1	306
	Bd. ft.	22,880	126,060	19,130	150	168,220
Lincoln FS	Trees	55	124	17	0	196
	Bd. ft.	40,130	136,990	24,540	0	201,660
Totals	Trees	1,020	2,732	413	74	4,239
Means, per acre		6.581	17.626	2.665	0.477	27.349
Mean percentages		24.1	64.4	9.7	1.8	100.0
Totals	Bd. ft.	430,950	1,902,040	372,270	51,050	2,756,310
Means, per acre		2,780	12,271	2,402	329	17,782
Mean percentages		15.6	69.0	13.5	1.9	100.0

Table 10.--Distribution of trees and tree volumes by risk ratings (Piquett Creek Experimental Area)

Plot		Unit of measure	Risk rating 1	2	3	4	Totals
Control:	B	Trees	18	353	58	4	433
		Bd. ft.	15,970	288,670	63,290	7,790	375,720
	D	Trees	12	282	59	3	356
		Bd. ft.	5,600	195,990	83,150	3,750	288,490
	G	Trees	35	391	43	2	471
		Bd. ft.	25,180	271,330	37,640	2,320	336,470
	J	Trees	31	474	82	3	590
		Bd. ft.	24,200	372,640	101,060	1,160	499,060
	O	Trees	20	185	25	3	233
		Bd. ft.	32,050	181,600	25,790	3,160	242,600
	Q	Trees	75	352	47	1	475
		Bd. ft.	39,780	271,710	42,200	660	354,350
Treatment I:	C	Trees	74	267	54	2	397
		Bd. ft.	45,020	183,850	59,210	1,090	289,170
	F	Trees	10	411	54	10	485
		Bd. ft.	3,740	344,550	55,430	10,180	413,900
	H	Trees	25	309	58	8	400
		Bd. ft.	3,360	239,060	80,890	10,720	334,030
	K	Trees	20	375	120	29	544
		Bd. ft.	5,920	236,680	80,540	24,010	347,150

Table 10.--Distribution of trees and . . . (Piquett Creek Experimental Area) (continued)

Plot		Unit of measure	Risk rating 1	2	3	4	Totals
Treatment I:	L	Trees	17	240	103	34	394
		Bd. ft.	15,550	244,880	117,230	49,010	426,670
	P	Trees	46	263	33	2	344
		Bd. ft.	45,610	241,430	24,330	3,410	314,780
Treatment II:	A	Trees	4	277	54	5	340
		Bd. ft.	630	164,530	63,560	4,000	232,720
	E	Trees	16	408	77	12	513
		Bd. ft.	5,990	356,000	94,930	11,540	468,460
	I	Trees	28	341	48	9	426
		Bd. ft.	23,170	280,730	55,040	6,050	364,990
	M	Trees	22	405	75	17	519
		Bd. ft.	15,950	338,240	73,920	26,000	454,110
	N	Trees	5	309	58	20	392
		Bd. ft.	4,040	335,590	92,660	36,480	468,770
	R	Trees	58	254	72	11	395
		Bd. ft.	44,550	191,450	60,250	12,360	308,610
Totals		Trees	516	5,896	1,120	175	7,707
Means, per acre			1.297	14.818	2.815	0.440	19.369
Mean percentages			6.7	76.5	14.5	2.3	100.0
Totals		Bd. ft.	356,310	4,738,930	1,211,120	213,690	6,520,050
Means, per acre			895	11,910	3,044	537	16,386
Mean percentages			5.5	72.7	18.5	3.3	100.0